Effectiveness of Lime-Sulfur and Phosphorous Acid for Controlling Summer Diseases on Apples

Project Leader:

David Rosenberger, Professor of Plant Pathology, Cornell's Hudson Valley Lab

Peter Jentsch, Entomology Research Support Specialist, Cornell's Hudson Valley Lab

Abstract: Liquid lime sulfur (LLS) was applied to apples at various rates and timings to determine its effectiveness for controlling sooty blotch, flyspeck, and summer fruit rots. Four applications of LLS at either 2 qt or 4 qt controlled flyspeck just as well as four sprays of Topsin M plus Captan (the commercial standard). Four applications of LLS at 1 qt/100 gal were less effective, but applying the low rate six times improved performance to equal that of the standard treatment. Two phosphorous acid products, Phostrol and NutriPhyte, were substituted for captan in several summer sprays and also provided effective control of sooty blotch and flyspeck. Measurements of the spray solution pH and surface residue pH from newly sprayed leaves verified the alkaline nature of LLS sprays and raised the possibility that LLS sprays could cause rapid breakdown of products that are subject to alkaline hydrolysis (e.g. Imidan), thereby compromising effectiveness of those products for controlling apple maggot. No apple maggot damage was observed in test plots, but the incidence of apple maggot damage was low throughout the region in 2006. Based on this trial, organic farmers could adopt LLS sprays during summer to control sooty blotch and flyspeck, but additional work is needed to determine if summer sprays of LLS sprays adversely affect fruit size or productivity of the sprayed trees. The PA products provide interesting alternatives for controlling summer diseases on apples, but considerable additional work is required to determine how these low-risk fungicides can be used to best advantage in apple spray programs.

Background and Justification: Liquid lime-sulfur (LLS) is gaining renewed interest as a control for apple diseases in both organic and "green" apple production systems, but it has not been widely tested for controlling flyspeck, sooty blotch, and summer fruit rots in eastern United States. In a 2005 field trial, LLS was as effective or more effective than Topsin M, Flint, Sovran, or Pristine for controlling flyspeck (Rosenberger & Meyer, 2006). Appropriate rates and optimum spray timing for summer applications of LLS have not been determined under conditions in the Northeast, nor do we know if this extremely caustic product might reduce effectiveness of summer insecticides that are subject to alkaline hydrolysis. Rates of LLS recommended for controlling apple scab resulted in some phytotoxicity to fruit in 2005. LLS is also known to reduce yields. However, if lower rates of LLS could be used to control summer diseases, then risks of both phytotoxicity and adverse effects on yield might be reduced. If effective, low rates of LLS during summer would provide a novel option for control summer diseases on organic fruit farms.

Phosphorous acid (PA) has also shown promise for controlling sooty blotch and flyspeck (SBFS) in North Carolina (Sutton et al., 2006). Several PA products are labeled for apples to control bacterial diseases (fire blight, blister spot) and root decays caused by *Phytophthora* species. The EPA label for ProPhyte was recently changed to include sooty blotch and flyspeck, and other labels for PA products will probably be changed as efficacy data becomes available. The PA fungicides could provide growers with low-risk, low-cost options for controlling apple diseases during summer.

Objectives:

1. Determine effective rates and timings for lime sulfur and phosphorous acid applications aimed at controlling flyspeck and sooty blotch, and summer fruit rots on apples.
2. Determine if lime sulfur and phosphorous acid applied a day or two after spinosad (Entrust) has been applied will reduce the effectiveness of this insecticide for controlling apple maggot and leafhoppers.
3. Project evaluation: Using data from the objectives above, determine the effectiveness and usefulness of lime sulfur and phosphorous acid for controlling summer diseases and publish the final report in *NY Fruit Quarterly*.

Procedures:

Based on previous work, assumptions at the start of this trial were (i) that flyspeck ascospores are released beginning at about petal fall, but that the ascospores are of relatively minor importance on apples because they are controlled by early season sprays for apple scab; (ii) conidia produced on hosts in orchard perimeters are blown into orchards starting at about 270 hr of accumulated wetting counting from petal fall and account for most fruit infections; (iii) after flyspeck conidia land on apple fruit, the flyspeck fungus requires 270 hr of accumulated wetting (hr-aw) in the absence of fungicide inhibition before lesions appear on fruit; (iv) that fungicides would arrest growth of flyspeck on fruit for the shorter of either 21 days or the period required to accumulate two inches of rain.

Treatments were applied in a randomized block design in a 9-yr-old orchard containing Golden Delicious (GD) apples on MM.111 rootstocks with M.9 interstems. The test block has poor air drainage and is surrounded by hedgerows and woodlots on three sides. Treatments were replicated four times in plots containing one tree of each cultivar. Sprays were applied to drip using a handgun and a high-pressure sprayer set at 200 psi. Early season fungicides were applied to prevent scab, rust, and mildew. The last scab fungicides (Nova 40W 3.3 oz/A + Polyram 80DF 2.7 lb/A) were applied on 8 Jun using an airblast sprayer. Protection from this application was depleted by 25 Jun when heavy rains brought the total rain accumulation since 8 June to 2.77 inches. Hr-aw from petal fall totaled 324 on 24 Jun, so flyspeck conidia from non-orchard hosts were available for infecting fruit when fungicide residues were depleted on 25 Jun. Fungicide protection from the 31 Aug sprays was depleted by heavy rains on 14 Sep. From 14 Sep until harvest on 3 Oct, fruit were exposed to 181 hr-aw, bringing the total potential flyspeck incubation period to 276 hr-aw when protection gaps earlier in the summer were added to the 181 hr-aw prior to harvest. Dates for fungicide applications are shown in Table 1.

Beginning on 21 Aug, 25 fruit per tree were observed for flyspeck without detaching fruit from the trees. Fruit were considered infected if any flyspeck colonies were observed anywhere on the fruit. The same method was used to re-evaluate fruit at arbitrary intervals until harvest. Fruit were harvested on 3 Oct (50 fruit per tree or all available if less than 50) and were observed for flyspeck, sooty blotch and fruit rots. Severity of SBFS was assessed by determining the proportion of harvested fruit that would not meet the USDA Extra Fancy grade solely because of these infections.

Objective 2 was modified because, when queried before the trial was initiated, the manufacturer informed us that Entrust was very stable within the pH ranges that we might encounter during this trial. However, many commercial growers use Imidan for late summer apple maggot sprays, and Imidan is susceptible to alkaline hydrolysis. LLS is known to have a high pH and therefore might degrade Imidan residues if the LLS sprays affect leaf surface pH. We applied Imidan on to control apple maggot on 11 and 19 July 7 and 22 August and evaluated fruit for apple maggot injury at harvest.

To further elucidate potential effects of LLS and PA products on leaf surface pH, we measured the pH of these products in the original containers, after mixing in the sprayer tank, and within several minutes of after applications on 31 Aug. The latter measure was taken by collecting spray droplets from the tips of leaves in each field replication and by using a portable pH meter to determine pH of the accumulated droplets in the field. Leaf surface pH was also evaluated 24 hr after the 31 Aug spray using the following method: Ten leaves per tree were collected and place on paper towels on a lab bench. The leaves were atomized with distilled water until visible droplets were evident on the leaf surfaces. After five minutes, the droplets were decanted from the leaf surfaces and the pH was measured.

Results:

Appearance of flyspeck on unsprayed fruit on 21 Aug was consistent with model predictions because by 21 Aug these fruit had been exposed to 276 hr-aw without fungicide protection. All of the treatments delayed flyspeck development, but some were more effective than others (Table 2).

Four applications of LLS at either 2 qt or 4 qt controlled flyspeck just as well as four sprays of Topsin M plus Captan (the commercial standard). Four applications of LLS at 1 qt/100 gal were less effective, but applying the low rate six times improved performance to equal that of the standard treatment. None of the harvested fruit were out-of-grade due to SBFS where LLS was applied six times at the low rate (Table 3). Weather conditions after bloom resulted in high variability in fruit russetting at harvest, and none of the treatments were significantly different from one another. Numerically, however, the LLS treatment at 4 qt/100 gal produced one of the highest means for percentage of fruit down-graded due to russet whereas the LLS treatments at 1 qt had means comparable to the better standard treatments. Thus, the results provide some indication that using reduced rates of LLS might reduce fruit damage that is sometimes associated with LLS sprays.

The six-spray program with Phostrol (a phosphorous acid product that is labeled for disease control) and Nutri-Phite (a similar product with no disease control label) provided better SBFS control on GD than a four-spray program of Captan alone. However, Topsin was included in the first spray and Captan was included in the last two sprays in the Phostrol and Nutri-Phite programs, so it is impossible to determine from this trial whether these products are active in their own right, whether they enhance activity of Captan, or whether their activity against SBFS is due to a combination of factors.

The pH meter malfunctioned mid-way through the process of measuring pH in the field on 31 August, so we were unable to determine pH for all treatments (Table 4). However, the pH of LLS solutions was clearly dependent on the concentration used. When measured on the leaf surface immediately after application, both the 2 qt and 4 qt rates produced leaf surface residues with pH above 8. That level of alkalinity can cause rapid degradation of Imidan. However, apple maggot pressure throughout the Hudson Valley was very light in 2006 and no damage was apparent in any of the plots in this trial.

Discussion:

Results from this trial show that organic apple growers could effectively control sooty blotch and flyspeck with regular applications of LLS at 1 qt per 100 gallons of dilute spray. In another trial conducted at the Hudson Valley Lab in 2006, wettable sulfur applied with an airblast sprayer during summer failed to control sooty blotch and flyspeck. Additional work is needed to answer the following questions related to LLS applications during summer:

1. The low rate of LLS (1 qt/100 gal) should be tested a trial where sprays are applied with an airblast sprayer to verify that airblast applications will be as effective as the handgun applications were in this trial.
2. LLS and wettable sulfur should be compared directly to verify that LLS is more effective for controlling flyspeck because the older literature suggests that LLS is more likely than sulfur to cause phytotoxicity and to adversely effect yield.
3. LLS applied at higher rates (2.5 gal/A) shortly after bloom can be used as a fruit thinner because it limits photosynthesis, slows fruit growth, and causes some fruit to drop from the tree. Additional work is required to determine if repeated summer application of LLS at 1 qt/100 gal or 3 qt/A will adversely affect fruit size and/or long-term productivity of trees.
4. Incidence of black rot and white rot was relatively low in this trial (Table 3). In other work, sulfur sprays sometimes exacerbate black rot, perhaps by injuring fruit lenticels and thereby providing an infection site. Further work is needed to verify that LLS can be used without adversely affecting the incidence of summer fruit rots.
5. Before LLS sprays can be adopted by non-organic growers, additional trials are needed to determine if the high pH of LLS sprays will compromise control of apple maggot by degrading insecticide residues (especially for Imidan) on fruit surfaces.

The activity of PA products for controlling sooty blotch and flyspeck suggests that these products might provide effective alternatives to the standard combination of Topsin M plus Captan that is currently used to control SBFS and summer fruit rot diseases. The PA products provide interesting alternatives for controlling summer diseases on apples, but considerable additional work is required to determine how these low-risk fungicides can be used to best advantage in apple spray programs.

Information generated from this research will be of interest primarily to organic farmers in New York and New England where SBFS can severely limit marketability of organically produced apples. PA products may gain wider applications among all fruit growers as we accumulate more data concerning their effectiveness for various diseases and potential problems related to their use.

Literature cited:

Rosenberger, D.A. and Meyer, F.W. 2006. Post-infection control of flyspeck with new fungicides, 2005. Fungicide and Nematicide Tests (online.) Report 61:PF024. DOI:10.1094/FN61. The American Phytopathological Society, St. Paul, MN.

Sutton, T.B., Brown, E., Anas, O., Meister, C.W. 2006. Efficacy of phosphorus-containing fungicides on summer diseases of apples, 2005. Fungicide and Nematicide Tests (online.) Report 61:PF004. DOI:10.1094/FN61. The American Phytopathological Society, St. Paul, MN.

Table 1. Application schedules for treatments applied in this trial.

Material and rate of formulated product per 100 gal of dilute spray [a]	Jun 30	July 10	July 19	July 28	Aug 10	Aug 31
Nutri-Phite Magnum 20 fl oz	Xt[b]	X	X	X		
mixed with Captan 80W 10 oz					Xc[b]	Xc[b]
Phostrol 20 fl oz...	Xt[b]	X	X	X		
mixed with Captan 80W 10 oz					Xc[b]	Xc[b]
Liquid lime-sulfur 1 qt (6 applications)........................	X	X	X	X	X	X
All other treatments	X		X		X	X

[a] The last scab fungicides (Nova 40W 3.3 oz/A + Polyram 80DF 2.7 lb/A) were applied 8 June; treatments were then applied on dates indicated.

[b] Combined with Topsin M 70WDG 4 oz (Xt) or with Captan 80W 10 oz (Xc)

Table 2. Development of flyspeck on fruit in late summer as affected by fungicide treatments.

Material and rate of formulated product per 100 gal of spray	% Golden Delicious fruit with flyspeck						
	Aug [a] 21	Aug [a] 28	Sep [a] 6	Sep [a] 18	Sep [a] 22	Sep [a] 27	Oct [b] 3
Control	22 b [c]	51 b	100 c	100 d	100 d	100 d	100 g
Nutri-Phite 20 fl oz (30 Jun—28 Jul) [d] + Captan 80W 10 oz (10, 31 Aug) ..	0 a	0 a	0 a	0 a	0 a	4 ab	14 cd
Phostrol 20 fl oz (30 Jun—28 Jul) + Captan (10, 31 Aug) [d]	0 a	0 a	0 a	0 a	1 ab	0 a	5 abc
Liquid lime-sulfur 1 qt (6 appl.) [d]........	0 a	0 a	0 a	0 a	4 ab	10 b	8 bc
Liquid lime-sulfur 1 qt (4 appl.) [d]........	0 a	0 a	12 b	19 c	27 c	30 c	32 ef
Liquid lime-sulfur 2 qt	0 a	0 a	0 a	0 a	4 ab	10 b	7 abc
Liquid lime-sulfur 4 qt	0 a	0 a	0 a	0 a	1 ab	2 ab	1 a
Captan 80W 10 oz...........................	0 a	0 a	8 b	25 c	36 c	44 c	44 f
Flint 50W 0.67 oz	0 a	0 a	0 a	0 a	6 b	11 b	19 de
Sovran 50W 1.33 oz	0 a	0 a	0 a	3 ab	6 b	7 ab	11 cd
Pristine 38 W 4.8 oz	0 a	0 a	0 a	0 a	2 ab	5 ab	5 abc
Captan 80W 10 oz + Topsin M 70 WDG 4 oz[v].........	0 a	0 a	0 a	4 b	2 ab	4 ab	4 ab

[a] Twenty-five fruit/tree were observed on the tree for flyspeck on dates indicated.

[b] Fifty Golden Delicious per tree (or all available fruit) were harvested on 3 Oct. Actual numbers harvested per tree ranged from 28 – 51 with a mean of 49.

[c] Numbers within columns followed by the same small letter do not differ significantly Fisher's Protected LSD P=0.05. The angular transformation was used for statistical analysis and arithmetic means are reported.

[d] For details of application schedule, see Table 1.

Table 3. Disease incidence and russetting on Golden Delicious at harvest.

Material and rate of formulated product per 100 gal of spray	% Golden Delicious fruit harvested 3 Oct[a] out of grade due to SBFS[b]	fly-speck	sooty blotch	black or white rot	out of grade due to russet[c]
Control	100 g[d]	100 g	100 e	7 a	44 a
Nutri-Phite 20 fl oz (30 Jun—28 Jul) + Captan 80W 10 oz (10, 31 Aug)	5 bcd	14 cd	3 ab	1 a	79 a
Phostrol 20 fl oz (30 Jun—28 Jul) + Captan (10, 31 Aug)	1 ab	5 abc	0 a	2 a	68 a
Liquid lime-sulfur 1 qt (6 appl.)	0 a	8 bc	1 ab	7 a	54 a
Liquid lime-sulfur 1 qt (4 appl.)	15 e	32 ef	23 d	6 a	54 a
Liquid lime-sulfur 2 qt	3 abc	7 abc	5 abc	5 a	50 a
Liquid lime-sulfur 4 qt	1 ab	1 a	1 ab	15 a	73 a
Captan 80W 10 oz	30 f	44 f	14 cd	5 a	52 a
Flint 50W 0.67 oz	10 de	19 de	9 bcd	4 a	68 a
Sovran 50W 1.33 oz	6 cde	11 cd	6 abc	3 a	53 a
Pristine 38 W 4.8 oz	1 abc	5 abc	3 ab	2 a	68 a
Captan 80W 10 oz + Topsin M 70 WDG 4 oz[v]	0 a	4 ab	0 a	5 a	60 a

[a] Fifty Golden Delicious per tree (or all available fruit) were harvested on 3 Oct. Actual numbers harvested per tree ranged from 28 – 51 with a mean of 49.

[b] Percent fruit that did not meet standards for USDA Extra Fancy due to the combination of flyspeck and sooty blotch.

[c] Percent fruit that did not meet standards for USDA Extra Fancy due to fruit surface russetting.

[d] Numbers within columns followed by the same small letter do not differ significantly Fisher's Protected LSD P=0.05. The angular transformation was used for statistical analysis and arithmetic means are reported.

Table 4. pH of liquid lime-sulfur and phosphorous acid products, and pH of leaf surface residues at the time of application and 24 hours later.

Product	Undiluted product	As mixed in sprayer	Leaf run-off 2 min after spraying	Leaf surface after 24 hours
Captan 80W 10 oz	n.d.	7.3	7.3	7.6
Phostrol 20 fl oz	6.6	6.7		
Nutri-Phite 20 fl oz	6.3	6.7		
Captan 80W 10 oz				
+ Phostrol 20 fl oz	n.d.	n.d.	n.d.	7.2
+ Nutri-Phite 20 fl oz	n.d.	n.d.	n.d.	7.8
Liquid lime-sulfur 4 qt	10.9	9.37	8.5	7.8
Liquid lime-sulfur 2 qt	10.9	9.02	8.7	7.7
Liquid lime-sulfur 1 qt	10.9	8.73	n.d.	7.5

Water pH before adding any fungicide was 7.7; n.d. = no data available.